EARTHWORM ACTIVITIES AND THE BREAKDOWN OF ORGANIC MATTER IN AGRICULTURAL SOILS

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Introduction

Although much remains to be discovered about the litter-decaying processes and their effect on the soil structure, it is very likely that the earthworms not only play an important part in this, but are even indispensable, especially for providing a good structure. The earlier studies in this field, particularly by MÜLLER (1887), led to this conclusion. Müller's visual examination of the A0-horizon in forest soils showed the following two humus types:

1. mor, characterized by a slow disappearance of dead plant matter deposited on surface of the soil, which is evidenced by the formation of a sometimes thick L-, F-, and H-layer on a more or less podsolized soil;

2. mull, typical for soils in which the organic material is rather rapidly and completely removed from the surface.

Organisms predominating in mor soils are well known for their habit of removing very little or no dead matter to deeper layers of the soil. Their casts are mainly placed on the surface, and nearly no mixing with the mineral soil occurs. In mull soils Lumbricidae are presumably the main cause for removing decaying plant remains from the top, involving the formation of water-stable aggregates with clay minerals, which is reflected in the crumble structure of such soils.

This article deals with the results of a study on the relationships between the development of earthworm populations and the breakdown of organic material in agricultural soils of both the old and new land. As the extent of decomposition of plant residues was to be estimated by visual examination of the A0-horizon, only grassland and grassed orchards, both having a rather undisturbed profile, have been considered.

Field observations

In this country, at least in old land, the soils of grassland appear to have naturally dense worm populations, which is in keeping with the formation of typical mull soils. On the contrary, in new polders there are originally no worms. So, in the Noordoost-polder, which has been cultivated since about 1947, there are still many areas where, even under a grass cover, no or nearly no worms occur. This seems to be reflected in an actual accumulation of undecayed material on the surface.

However, there is no rule without exception. So, many of the striking examples of mor formations were found on old land. In the Province of Zeeland, for instance, particularly in Walcheren and near Kruiningen, there are areas where after inundations during periods of about six months, in 1944 and in 1953 respectively, the earthworm populations died out. In these areas nowadays grasslands occur with a thick mat of undecayed grass debris on top of the soil, presumably due to no or nearly no earthworms being present there. Further evidence of such atypical formations in the profile was shown in mull soils of grassed orchards which had been exposed to high volume spraying for years. Especially under the fruit trees which had been treated with copperoxychloride during several years, a striking agreement between the absence of earthworms and the mat formation was observed (Fig. 1). This points to an interruption in the breakdown or removal of plant remains by earthworms. An analysis of the soil and the litter revealed rather high Cu contents of about 80 p.p.m. in the soil and 75 p.p.m. in the litter of the sites under these copper-sprayed trees, against 7—18 p.p.m. in the soil under the trees which had not been treated with copper. Similar phenomena occurring in orchards treated with Bordeaux mixture have already been mentioned by HIRST et al. (1961).

In newly reclaimed land the deviations to the general mor formation are only evidenced in those areas, where in the meantime earthworm populations had developed, e.g. after inoculating these sites. Particularly a 7-year old pasture at the Lovinkhoeve, an experiment farm in the Noordoost polder, should be mentioned. In 1960 populations here occurred with an average density of 280 per m^2 and an average fresh weight of 175 g. The composition of the species was 72.5 % *Allolobophora caliginosa*, 18.5 % *Allolobophora longa* and 8.5 % *Lumbricus rubellus*. Further there is another example, in a fruit plantation near Marknesse, where in 1960 a nearly 100 % *Allolobophora caliginosa* population with a density of 140—500 per

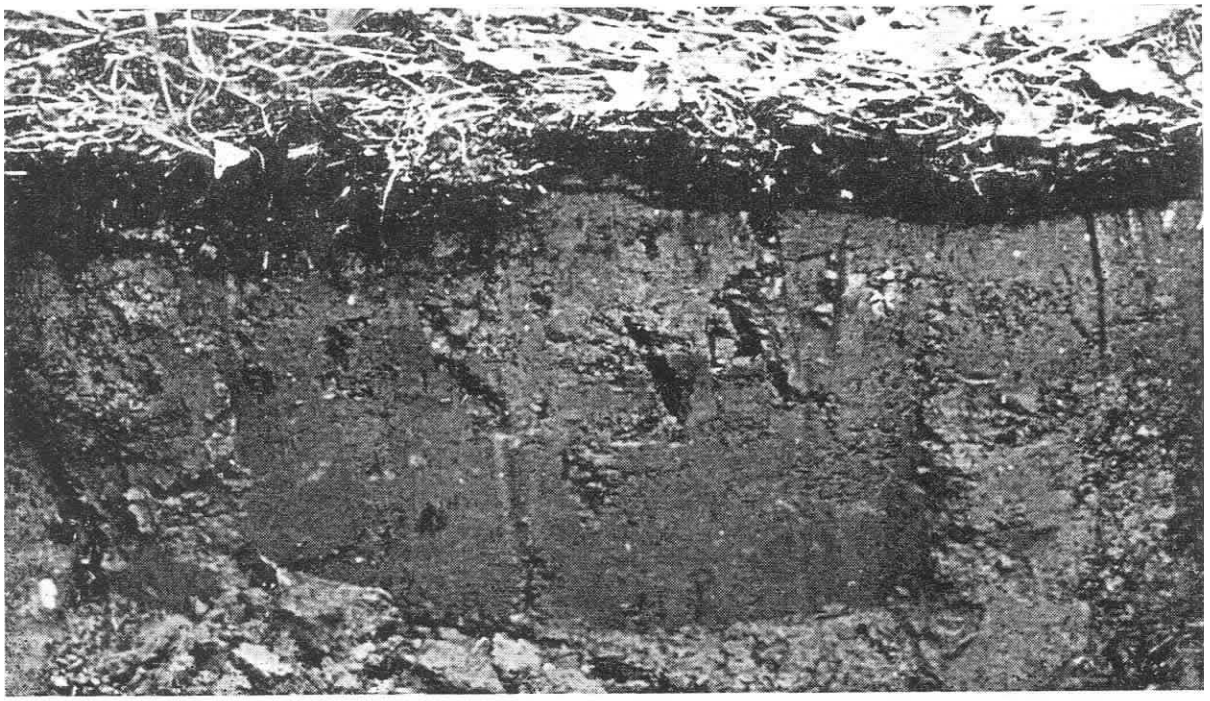

Fig. 1. Surface mat formation in copper sprayed orchard.

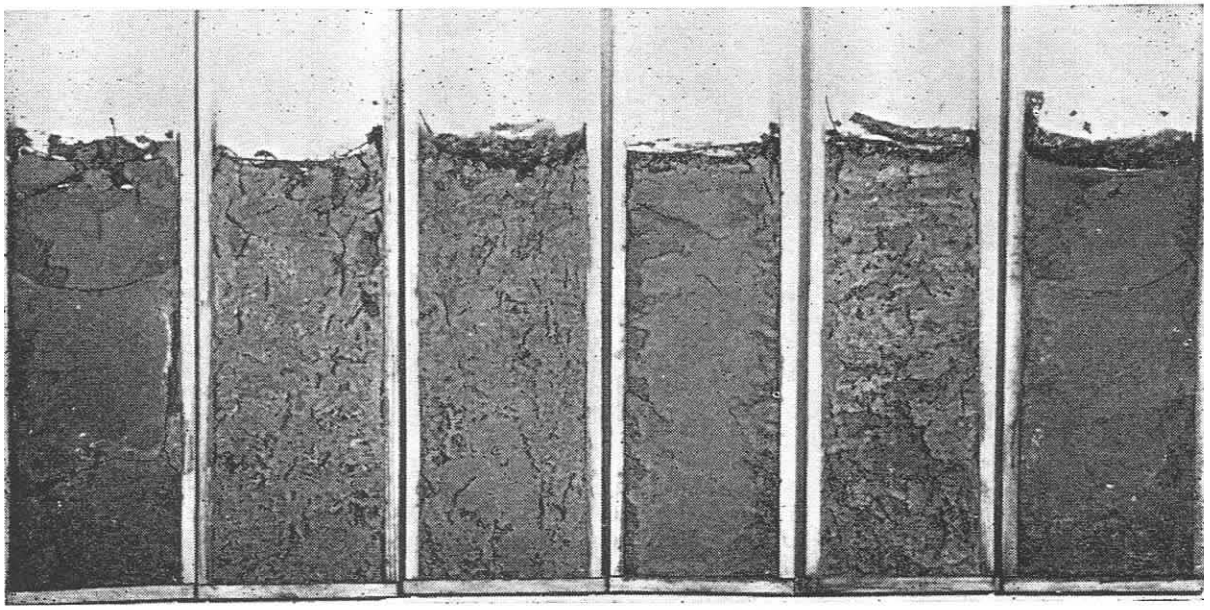

Fig. 2. Cages experiment with alder leaves at the surface .

From left to right: *L.terrestris*, *A.caliginose*, *A.rosea*, *L.castaneus*, *A.chlorotica* *and control.*

m^2 and an average weight of 50—125 g had developed, after this orchard had been inoculated in 1947. On both sites the earthworm activity locally was expressed in a typical mull soil, while in adjacent areas with few or no worms the mor formations are still predominating.

In Walcheren and in the Noordoost-polder field experiments are now undertaken for removing those layers of undecayed material by introducing earthworms. From September 1961 on, several times, viz. every month or every two months, very small plots were inoculated separately with certain species of earthworms. In the experiments carried out in Walcheren, only the inoculations with *Allolobophora longa* were successful. Right on the site where in total 400 specimens of this species were introduced, the accumulation of litter began to decrease within a year. This phenomenon in addition to the examples set forth before, suggests that some pasture-inhabiting species actually do contribute to the formation of mull soils instead of mull conditions favouring the development of earthworms, though indeed there may be a mutual influence.

Activities of earthworms in artificial profiles

Experimental results pertaining to the feeding habits of earthworms explain the close relationship between earthworms and humus form.

Comparative studies were performed to assess the behaviour of several species, especially in connection with their consumption of different organic material under laboratory conditions. These experiments were made in artificial profiles, closed in cages of 45 cm height and 15 cm width, constructed of two plates of perspex which are held together by spring clips with pieces of wood (1.5 cm thick) inserted between the perspex sides. These cages were filled with air-dried soil which had been pounded beforehand, and screened through a 1 mm-mesh sieve. The soil was then packed down, and after moistening by soaking the cages, the earthworms were put in. The layer of organic material to be examined (alder leaves, fresh grass, and material derived from over mentioned mat formations in grasslands and in orchards) was placed on top of the soil, after the earthworms had burrowed in.

A photograph made of one of these series (Fig. 2) shows marked differences in behaviour between different earthworm species. *Lumbricus terrestris* e.g., and also *Allolobophora longa*, obtain their food on the surface, while making only one or a few vertical burrows, at the entrance of which

these species excrete a considerable amount of soil. The alder leaves were nearly all digested below the surface. So it could be observed that the removal of the leaves by *Lumbricus terrestris* had already been completed even before the onset of fragmentation. Under these conditions even the woody veins disappeared, probably also digested by the earthworms.

From the photograph it seems that a nearly similar biomass of the small *Allolobophora* species *(A. caliginosa, A. chlorotica* and *A. rosea)* attacks the soft tissues of leaves at the surface, leaving only the woody veins. In a short space of time many ramifying burrows are made. It was further noticed that they fill up their burrows with excreta, instead of casting on the surface.

These experiments show not only how earthworms do contribute to the breakdown of organic matter, but they may also provide a rough estimate of their food consumption (Table 1).

TABLE 1. Food consumption in mg/g fresh weight/day

	Set A Fresh grass Oven-dried	Set B Alder leaves Air-dried	Set C Undecayed material under Cu-treated fruit trees. Oven-dried	Set D Undecayed material in grassland with little worm activity. Air-dried
L. terrestris	17	10	66	40
A. longa	—	—	43	57
A. caliginosa	12	12	47	32
A. rosea	12	10	17	
A. chlorotica	12.5	12	—	
L. castaneus	—	33	—	—

From these figures it may be deduced that the rate of consumption principally depends on the quality of organic matter. The rather low consumption of fresh grass and alder leaves suggests these foodstuffs to be more nutritious to earthworms than the other material. With the large species (viz. *Lumbricus terrestris* and *Allolobophora longa)* the organic matter in general disappears a little faster, except in the B sets, where *Lumbricus castaneus* shows an exceptionally high consumption of leaf material. This suggests that the small *Allolobophora* species either feed more on micro-organisms contained in the soil, or digest the leaf tissues more completely.

Organic matter from which earthworms were excluded (control cages), seemed to remain intact, at least when visually considered. However, a decline of the initial weight of organic matter in the control cages (i.e. in the A set 43 %, in the B set 43 % and in the D set 30 %) indicates a rather high activity of micro-organisms. In the control of the C sets there was no loss of weight of the organic material. The high Cu-content of the plant debris in this sets may have decreased the amount of fungi and bacteria so that here no digestion of plant remains could take place at all. The interrelationships between earthworms and micro-organisms being very complex, it would be very speculative to take into account this microbial attack.

The preliminary results obtained show the usefulness of the techniques used, but more experiments remain to be undertaken to show the causal relationships between the breakdown of organic matter and the activities of earthworms and micro-organisms and their interactions as well.

Summary

Observations on the breakdown or disappearance of plant remains in grassland and grassed orchards show a striking correspondence with the activities of earthworms. In old land, in general being rich in earthworms, mull soils are evident, while in newly reclaimed land the absence of earthworms coincides with mor formations. Field experiments with different earthworm species show *Allolobophora longa* to induce the mull humus type. In laboratory experiments only little differences in decomposing activities are evident. Exclusion of earthworms retards the breakdown of organic matter to a considerable extent.

References

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